Dear Editor,

Thank you very much for your consideration of our manuscript (nhess-2021-200) for the potential publication and your suggestions about the major revision. We have revised the manuscript according to the reviewers' suggestions, and proof-read the manuscript to minimize typographical, grammatical, and bibliographical errors. We prepared three documents as requested: (1) a point-to-point reviewer response document including original comments, our response, and corresponding revisions made in the manuscript, (2) a marked-up manuscript version showing all the detailed modifications in the manuscript, and (3) a revised manuscript.

We appreciate your kind help in the process of review and revision. We look forward to further updates from you.

Sincerely,

Qinke Sun
On behalf of the co-authors

Reply to the Editor Javier Revilla Diez

Comments to the author: I really enjoyed reading the revised version. You did tackle all the comments raised by the reviewers in a very sound way. The only thing to consider is an ammendment to the title. As you focus on Shanghai, I wonder whether you should add this to the title - ... as examplified with or illustrated by... But, I leave it to you.

Authors' Response: We would like to thank the Editor for handling our manuscript, and providing constructive comments to our research work. After thorough discussions with each of our collaborators, the title of the manuscript remains the same: "Multi-scenario urban flood risk assessment by integrating future land use change models and hydrodynamic models". The reason is that the manuscript focuses more on the integration of methods, which is to integrate future land use models and hydrodynamic models for multi-scenario flood risk assessment, and Shanghai is chosen as the validation area for the method. The research approach that we adopted can be extended to every low-lying coastal city.

Below is our response to comments from the two reviewers. We carefully addressed comments in the revised manuscript, as better specified below in this response letter. We also uploaded an annotated manuscript with track change. We would like to express our appreciation again for your efforts in managing the whole review process.

Response to Referee #1

The authors would like to thank the Anonymous Referee #1 for the insightful and constructive comments. We have reviewed the comments and provided our responses herein. We truly believe that the changes suggested by Referee #1 will enhance the quality of the manuscript. A point-by-point response is presented below.

R1: Thank you for letting me read the interesting manuscript that provides valuable results on urban flood risk scenarios for Shanghai. The manuscript fits the aims and scope of the Journal Natural Hazards and Earth System Sciences. The authors present their method and data transparently as well as provide a good presentation of the results. However, the manuscript lacks a general discussion of studies on urban flood risk assessment and a link of their findings to the literature. Therefore, I recommend the authors to add this to the manuscript. Also, I suggest a external language check. The manuscript includes some grammar mistakes. Next to smaller remarks I therefore recommend a major revision.

A1: We greatly appreciate your kind help in the reviewing the manuscript and all constructive comments. And we have revised the manuscript based on these comments and suggestions.

R11: However, the manuscript lacks a general discussion of studies on urban flood risk assessment and a link of their findings to the literature. Therefore, I recommend the authors to add this to the manuscript.

A11: The manuscript provides an insufficient discussion of urban flood risk assessment, and we thank the reviewers for raising this point which has greatly improved to the quality of the manuscript. The authors have added rephrased the second paragraph of the introduction to take into account the latest research findings on urban flood risk assessment. The Referee can read the following explanations in the revised manuscript.

Line 39-51: *However, high uncertainty in flood risk and urban growth leads to a* *lack of capacity of cities to respond to the flooding arising from future climate change (Du et al., 2015; Tessler et al., 2015; Fang et al., 2021). Therefore, there is an urgent need for specialist knowledge and techniques to address the conflict between urbanization and flood risk (Wang et al., 2015; Lai et al., 2016; Bouwer, 2018; Haynes et al., 2018). Studies on urban flood risk assessment are more likely to simulate flood risk using different climate change scenarios or integrating different flood sources (Huong and Pathirana, 2013; Muis et al., 2015; Dullo, 2021). For example, Zhou et al. examine the impact of urban flood volumes and associated risks under RCP2.6 and RCP8.5 scenarios (Zhou et al., 2019). Parodi et al. integrate the compound flood scenarios such as wave height, storm surge, and extreme sea level due to sea level rise to assess coastal flood risk (Parodi et al., 2020). However, ignoring the uncertainty of urban growth in urban flood risk assessment reduces the validity of the assessment (Gori, 2019), and hence an increased understanding of possible urban growth scenarios is needed, otherwise there is a lack of understanding of the consequences of future flooding (Zhao et al., 2017; Kim and Newman, 2020). Although there are some studies that have quantified future growth scenarios for urbanization (Nithila Devi, 2019; Lin et al., 2020), these studies have not considered the impact of existing planned policies that are designed to mitigate the impact of new development.*

[1] Du, S., Van Rompaey, A., Shi, P. and Wang, J.: A dual effect of urban expansion on flood risk in the Pearl River Delta (China) revealed by land-use scenarios and direct runoff simulation, Nat. Hazards, 77(1), 111–128, doi:10.1007/s11069-014-1583-8, 2015.

[2] Fang, J., Wahl, T., Zhang, Q., Muis, S., Hu, P., Fang, J., Du, S., Dou, T. and Shi, P.: Extreme sea levels along coastal China: uncertainties and implications, Stoch. Environ. Res. Risk Assess., 35(2), 405–418, doi:10.1007/s00477-020-01964-0, 2021.

[3] Tessler, Z. D., Vorosmarty, C. J., Grossberg, M., Gladkova, I., Aizenman, H., Syvitski, J. P. M. and Foufoula-Georgiou, E.: Profiling risk and sustainability in coastal deltas of the world, Science (80-.)., 349, 638–643, doi:10.1126/science.aab3574, 2015.

[4] Bouwer, L. M.: Next-generation coastal risk models, Nat. Clim. Chang., 8(9), 765–766, doi:10.1038/s41558-018-0262-2, 2018.

[5] Haynes, P., Hehl-Lange, S. and Lange, E.: Mobile Augmented Reality for Flood Visualisation, Environ. Model. Softw., 109, 380–389, doi: 10.1016/j.envsoft.2018.05.012, 2018.

[6] Lai, C., Shao, Q., Chen, X., Wang, Z., Zhou, X., Yang, B. and Zhang, L.: Flood risk zoning using a rule mining based on ant colony algorithm, J. Hydrol., 542, 268–280, doi:https: //doi.org/10.1016/j.jhydrol.2016.09.003, 2016.

[7] Wang, Z., Lai, C., Chen, X., Yang, B., Zhao, S. and Bai, X.: Flood hazard risk assessment model based on random forest, J. Hydrol., 527, 1130–1141, doi: 10.1016/j.jhydrol.2015.06.008, 2015.

[8] Huong, H. T. L. and Pathirana, A.: Urbanization and climate change impacts on future urban flooding in Can Tho city, Vietnam, Hydrol. Earth Syst. Sci., 17(1), 379–394, doi:10.5194/hess-17-379-2013, 2013.

[9] Muis, S., Güneralp, B., Jongman, B., Aerts, J. C. J. H. and Ward, P. J.: Flood risk and adaptation strategies under climate change and urban expansion: A probabilistic analysis using global data, Sci. Total Environ., 538, 445–457, doi: 10.1016/j.scitotenv.2015.08.068, 2015.

[10] Dullo, T. T., Darkwah, G. K., Gangrade, S., Morales-Hernández, M., Sharif, M. B., Kalyanapu, A. J., Kao, S. C., Ghafoor, S. and Ashfaq, M.: Assessing climate-change-induced flood risk in the Conasauga River watershed: An application of ensemble hydrodynamic inundation modeling, Nat. Hazards Earth Syst. Sci., 21(6), 1739–1757, doi:10.5194/nhess-21-1739-2021, 2021.

[11] Zhou, Q., Leng, G., Su, J. and Ren, Y.: Comparison of urbanization and climate change impacts on urban flood volumes: Importance of urban planning and drainage adaptation, Sci. Total Environ., 658, 24–33, doi:https: //doi.org/10.1016/j.scitotenv.2018.12.184, 2019.

[12] Parodi, M. U., Giardino, A., Van Dongeren, A., Pearson, S. G., Bricker, J. D. and Reniers, A. J. H. M.: Uncertainties in coastal flood risk assessments in small island developing states, Nat. Hazards Earth Syst. Sci., 20(9), 2397–2414, doi:10.5194/nhess-20-2397-2020, 2020.

[13] Gori, A., Blessing, R., Juan, A., Brody, S. and Bedient, P.: Characterizing urbanization impacts on floodplain through integrated land use, hydrologic, and hydraulic modeling, J. Hydrol., 568, 82–95, doi: 10.1016/j.jhydrol.2018.10.053, 2019.

[14] Kim, Y. and Newman, G.: Advancing scenario planning through integrating urban growth prediction with future flood risk models, Comput. Environ. Urban Syst., 82, 101498, doi:https: //doi.org/10.1016/j.compenvurbsys.2020.101498, 2020.

[15] Zhao, L., Song, J. and Peng, Z.-R.: Modeling Land-Use Change and Population Relocation Dynamics in Response to Different Sea Level Rise Scenarios: Case Study in Bay County, Florida, J. Urban Plan. Dev., 143(3), 04017012, doi:10.1061/(asce)up.1943-5444.0000398, 2017.

[16] Nithila Devi, N., Sridharan, B. and Kuiry, S. N.: Impact of urban sprawl on future flooding in Chennai city, India, J. Hydrol., 574, 486–496, doi: 10.1016/j.jhydrol.2019.04.041, 2019.

[17] Lin, W., Sun, Y., Nijhuis, S. and Wang, Z.: Scenario-based flood risk assessment for urbanizing deltas using future land-use simulation (FLUS): Guangzhou Metropolitan Area as a case study, Sci. Total Environ., 739, 139899,

R12: Also, I suggest a external language check. The manuscript includes some grammar mistakes.

A12: Thanks, we will correct all grammatical and language-related idiosyncrasies in our revised manuscript. We invite members of the team who are good at English and native English-speaking foreign partners to read the full manuscript carefully and help correct grammatical errors in the manuscript.

Minor recommendations

R2: Please do not use abbreviations, such GE or BU in the abstract.

A2: Thanks for your suggestion. We have replaced all abbreviations of BU, GU and GP that appear in the abstract.

R3: Please rephrase: “We also find that urban will tend to expand to areas vulnerable.” What is meant by urban? Urbanization?

A3: Thanks for noting this. We have rephrased this sentence accordingly in our revised manuscript. Revised as follows: "We also find that urbanization tends to expand more towards flood-prone areas under the restriction of ecological environment protection."

R4: What is meant by "coupling model" (line 24)?

A4: Thanks for the comment. In line 24, the "coupling model" is the method that couples the future land use simulation model (FLUS) and floodplain inundation model (LISFLOOD-FP). This sentence we want to express the research significance of the simulation results of the model, so we have rephrased the sentence for better expression. The Referee can read the new part in the following:

Line 24-26: *The increasing flood risk information determined by model simulations help to understand the spatial distribution of future flood-prone urban areas and promote the re-formulation of urban planning in high-risk locations.*

R5: Lines 31-32: "The United Nations reports that the global population will increase by 29% (7.6 billion) between 2017 and 2050 (United Nations, 2017b)," Is the increase taking place in coastal cities? If yes, please make this clear in the sentence.

A5: We thank the reviewer for raising this point which we believe may have been caused by lack of clarity in the manuscript. We have rephrased this sentence and also provide the supporting reference. The Referee can read the following explanations in the revised manuscript.

Line 31-35: *The United Nations reports that the global population living in cities is projected to reach 6.7 billion by 2050 (United Nations, 2018), especially in low elevation coastal areas, the population density is expected to be twice the current population density (Van Coppenolle and Temmerman, 2019), which means that population of coastal cities will become increasingly concentrated in the future and impervious surfaces will become more numerous (Chen et al., 2020; He et al., 2021)*

[1] United Nations: 2018 Revision of World Urbanization Prospects. https://population.un.org/wup/, 2018.

[2] Van Coppenolle, R. and Temmerman, S.: A global exploration of tidal wetland creation for nature-based flood risk mitigation in coastal cities, Estuar. Coast. Shelf Sci., 226, 106262,

doi: 10.1016/j.ecss.2019.106262, 2019.

[3] Chen, G., Li, X., Liu, X., Chen, Y., Liang, X., Leng, J., Xu, X., Liao, W., Qiu, Y., Wu, Q. and Huang, K.: Global projections of future urban land expansion under shared socioeconomic pathways, Nat. Commun., 11(1), 537, doi:10.1038/s41467-020-14386-x, 2020.

[4] He, C., Liu, Z., Wu, J., Pan, X., Fang, Z., Li, J. and Bryan, B. A.: Future global urban water scarcity and potential solutions, Nat. Commun., 12(1), 1–11, doi:10.1038/s41467-021-25026-3, 2021.

R6: Line 44: Please give some examples what is meant by "environmental factors".

A6: Thanks for the comment. Environmental factors in the manuscript include study area topography, study area water level conditions, etc. Because we have rewritten this part of the introduction in conjunction with the general comments, the environmental factors and other influencing factors are described in detail in the second part of the manuscript.

R7: Line 54: "The FLUS model improves the simulation accuracy of the model…" Which model will be improved?

A7: Thanks for the comment. We describe the FLUS model in detail in the methodology of the manuscript (Line 148-149), so we did not expand the description in the introduction.

Line148-149: *"The FLUS model is an upgraded version of a cellular automata model (Liu et al., 2017) which can solve the complex land use simulation problems by self-adaptive inertia and competition mechanism."*

R8: Please rephrase: "To answer this question, we first consider how urban grow under different environmental and planning factors in the future." (lines 61-62).

A8: We thank the reviewers for raising this point. We have rephrased the sentence. The Referee can read the new part in the following: *To answer this question, we first assume some future simulation scenario by considering the factors that influence* *urban growth and lead to flood risk.*

R9: Please include a presentation of the further content of the paper in the Introduction.

A9: Thanks for your comments. We have added a presentation of the further content in the introduction. The Referee can read the new part in the following:

Line 73-77: *The rest of paper is organized as follows: section 2 describes the characteristics of the study area and presents the data used in this paper; followed by a description of the methodology for integrating future land use change models and hydrodynamic models in Section 3. The results and discussion in Section 4 and Section 5. We divided the discussion section into two parts, on the one hand discussing the sources of uncertainty in the study, and the other part discussing adaptation policies for urban flood risk in the context of climate change. The conclusion of the study is described in Section 6.*

R10: Line 149-150: Can you please further explain why do you choose 2,768 km^2 in 2030 and 3,200 km^2 in 2050 as reasonable city growth pathways?

A10: Thanks for the comment. First of all, we base on the prediction results of Markov chain model that the urban area is 2768 km^2 in 2030 and 3270 km^2 in 2050, next, we combine the master plan of Shanghai requires that the total area of planned urban construction land does not exceed 3,200 km^2 in 2035. Therefore, we choose an urban area of 2768 km^2 in 2030 and 3200 km^2 in 2050 as the constraints under the GP scenario. We have rephrased this sentence in the manuscript. The Referee can read the following explanations in the revised manuscript.

Line 162-165: *We choose an urban area of 2768 km^2 in 2030 and 3200 km^2 in 2050 as the constraints under the GP scenario. The reason is that the Markov chain model projections result in an urban area is 2768 km^2 in 2030 and 3270 km^2 in 2050, and the total urban construction land area in 2035 of the Shanghai Master Plan does not exceed 3200 km^2.*

R11: Line 169-170: Please add some references to justify the useful applicability of the

LISFLOOD-FP model.

A11: Thank you very much for your suggestion. We have added some recent references to the manuscript. The Referee can read the following explanations in the revised manuscript.

Line 184-186: The model has been widely used in the applications of small-scale and large-scale urban waterlogging and flooding (Hoch et al., 2019; Rajib et al., 2020; Zhao et al., 2020).

[1]. Hoch, J. M., Eilander, D., Ikeuchi, H., Baart, F. and Winsemius, H. C.: Evaluating the impact of model complexity on flood wave propagation and inundation extent with a hydrologic-hydrodynamic model coupling framework, Nat. Hazards Earth Syst. Sci., 19(8), 1723–1735, doi:10.5194/nhess-19-1723-2019, 2019.

[2]. Rajib, A., Liu, Z., Merwade, V., Tavakoly, A. A. and Follum, M. L.: Towards a large-scale locally relevant flood inundation modeling framework using SWAT and LISFLOOD-FP, J. Hydrol., 581, 124406, doi: 10.1016/j.jhydrol.2019.124406, 2020.

[3]. Zhao, G., Bates, P. and Neal, J.: The Impact of Dams on Design Floods in the Conterminous US, Water Resour. Res., 56(3), 1–15, doi:10.1029/2019WR025380, 2020.

R12: Line 187: Please explain what is meant by the abbreviation LUCC.

A12: Thanks for your suggestion. LUCC is the land use/cover changes, we have added explanations before the abbreviation in the revised manuscript.

Line 207-208: The applicability of the proposed model was tested by simulating land use/cover changes (LUCC) in 2015 at Shanghai.

R13: I propose to include the explanations contained in the titles of the figures and tables in the text of the manuscript and to refer to the figures and tables.

A13: Thanks for the comment. The titles of the figures and tables in the manuscript are described with reference to the format of the journal with previous issues of the literature, in other words, the titles of the figures and tables in the manuscript are described in detail. We have also revised the descriptions of the figures and tables in the text of the manuscript to give more detail.

R14: Lines 250-253: I suggest presenting either relative numbers (in %) or the absolute number of inundated land area. For RCP2.6 scenario you are using the land area but for RCP 8.5 you present relative numbers.

A14: Thank for your suggestion. We have revised the sentences in the manuscript and checked for similar issues in the manuscript. The Referee can read the following explanations in the revised manuscript.

Lines 271-274: *Under the RCP2.6 scenario, new growth in urban land area affected by flooding in 2030 are respectively 55.11 km^2, 23.22 km^2, and 30.92 km^2 at BU, GP and GE scenarios. Under the RCP8.5 scenario, future more urban growth areas would be affected by the flooding, which will reach 115.53 km^2, 70.36 km^2, and 81.71 km^2 at BU, GP and GE scenarios in 2050, respectively.*

R15: Line 260-261: Please make clear whether this findings means in absolute and/or in relative numbers.

A15: Thanks for your comments. Inundation results in the study manuscript are absolute numbers. The findings from in our research are relative conclusions by comparing the absolute inundation numbers of different land types. We have rephrased this sentence in the corresponding place in the revised manuscript.

Line 281-282: *The research found that the cultivated land is the most affected land type by flooding relative to urban areas, woodland and grassland.*

R16: Line 329: "…range and spatial distribution of flood risk in future urban" Please add "areas" at the end of the sentence.

A16: Thank you very much for your suggestion. We have revised this sentence in the manuscript. The Referee can read the following explanations in the revised manuscript.

Line 351-352: *Additionally, the research provided significant insights into the range and spatial distribution of flood risk in future urban areas.*

Response to Referee #2

The authors would like to thank Anonymous Referee #2 for reviewing the paper and providing these thought-provoking perspectives. We really appreciate the comments and suggestions and have given them careful consideration. Below are our point-by-point responses to the comments. In addition, we really thank the referee's efforts in the in-depth analysis in the attached document, as well as his/her helpful indications, which certainly improved the quality of our manuscript. The Referee can find our corrections in the attached file entitled Replies to specific comments.

R1: The paper tackles an important subject in future management perspectives of coastal urban regions. Nevertheless, there are some major constraints/critisism to the current version of the paper. The land cover data set seems to be outdated (2014) and has only a coarse spatial resolution (100 m). Based on this, to model the year 2015 with land cover data from 2014 is not so difficult and shows a high coincidence as expected. Why not using a higher spatial resolution from Sentinel-2 (10 m) from the year 2020? Six years after the acquired land use data set from 2014 this would show whether the performance of the land use model is good enough or not...,

A1: Thanks for your comments. First, the FLUS model predicts future land use/land cover determined by the amount of future land use type demand and the driving factors affecting land change. Here we use a Markov chain model to predict the amount of future land use demand. The model requires at least two periods of historical land use data to predict the amount of land use for the same time interval in the next period. In predicting the future land use changes we used two steps to do so, one is the model testing and the other is the model prediction. We used two steps to predict future land use changes, one is model validation and the other is model prediction.

1. Model validation. **We predict the land use change in 2015 based on the land use data in 2010.** In this process, the quantity of land demand in 2015 was first

predicted by Markov chain model based on the land use data in 2005 and 2010, and then it was input into the FLUS model to simulate the type of land use in 2015. Finally, we compared the simulated results and the actual land use in 2015 pixel by pixel to test the reliable performance of the model.

2. Model prediction. After the model and impact factor selection were evaluated by reliability accuracy, we predicted the future land demand quantity in 2020, 2030, through Markov chain model based on the land use data in 2010 and 2015. Then we combine the impact factor data and the land demand quantity to predict the future land use results.

In addition, we have attempted to use high-resolution land use data (e.g., GlobeLand30) for prediction. The images for land cover classification of development and update of GlobeLand30 are mainly 30-meter multispectral images, including TM5 ETM+, and OLI multispectral images of Landsat (USA) and HJ-1 (China Environment and Disaster Reduction Satellite), the 16-meter resolution GF-1(China High Resolution Satellite) multispectral image are also used for GlobeLand30 2020. (http://www.globeland30.org/home.html?type=data). **We selected the land use data of GlobeLand30 for the periods of 2000, 2010, and 2020, and simulated the prediction of the study area by Markov chain model and FLUS model,** but the results were very unsatisfactory. We compared the simulation results for 2020 and found that kappa coefficient (kappa) was 0.64 and overall accuracy (OA) was 76.85%, and the producer accuracy was lower for each land use type. And we used 100 m land use data to produce an OA was 93.20% and a kappa was 0.89.

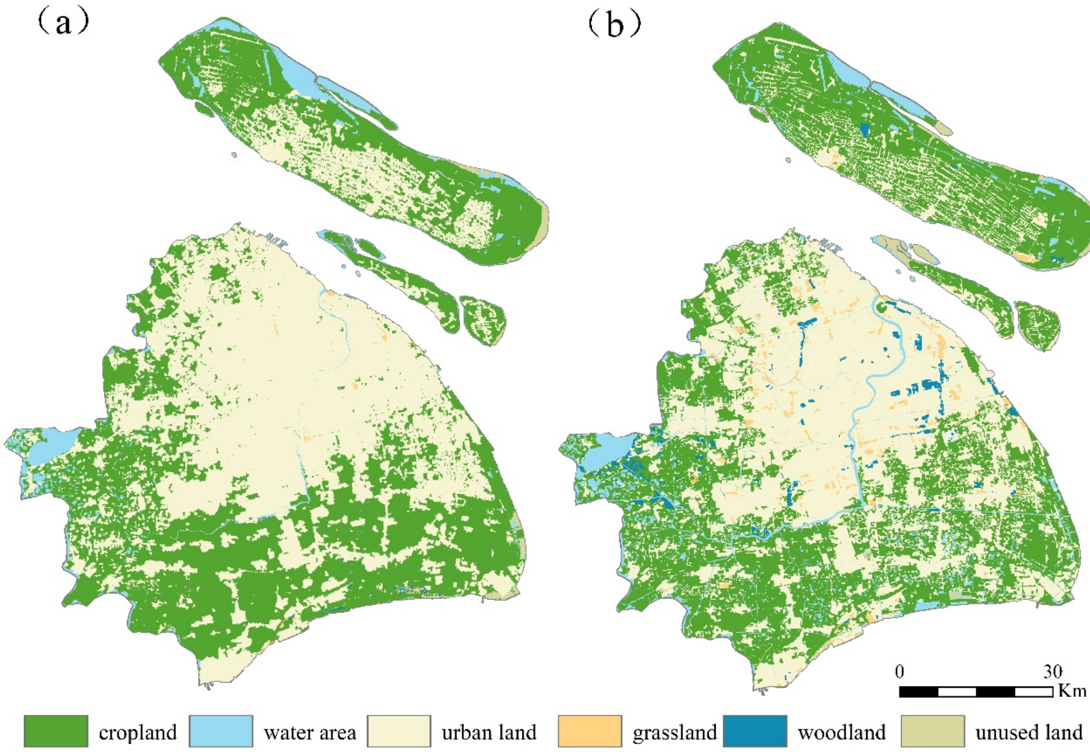

Figure 1: Comparing the simulation results using GLC30 data with the actual situation, (a) simulation result in 2020; (b) actual land use in 2020

Furthermore, our team also considered selecting 2020GLC data to be used with our data set, but there are more problems between different data due to the large differences in the production and classification standards. Meanwhile, the high precision Sentinel-2 has more detailed descriptions for spatial details (Claverie et al., 2019), but there is no long time series (10 years) and annual integrated land use classification product (Nurfadila et al., 2019). Related studies have demonstrated that medium-resolution (100 m) is more adequate to detect most human–nature interactions, while medium-high resolution sensors (Landsat 8/OLI and Sentinel-2/MSI) are more suitable for detailed studies of plant phenology (Chaves et al.,2020). Therefore, we chose this set of 100-m resolution land use data produced by the Chinese Academy of Sciences from the perspective of data consistency and accuracy of model simulation. In addition, we have analyzed the data for research limitations in the discussion section of this manuscript.

Thanks again to the Referee for the comments.

[1] Claverie, M., Ju, J., Masek, J., Dungan, J., Vermote, E., Roger, J., Skakun, S., Justice, C.: The Harmonized Landsat and Sentinel-2 surface reflectance data set. Remote Sens. Environ, 219, 145–161, 2018.

[2] Nurfadila, J., Baja, S., Neswati, R., Rukmana, D., Zylshal, Z.: Initial Results on Landuse/Landcover Classification Using Pixel-Based Random Forest Algorithm on Sentinel-2 Imagery over Enrekang Region, IOP Conference Series: Earth and Environmental Science, 280(1), 012036, 2019.

[3] Chaves, M., Picoli, M., Sanches, I.: Recent Applications of Landsat 8/OLI and Sentinel-2/MSI for Land Use and Land Cover Mapping: A Systematic Review, Remote Sens, 12, 3062, 2020.

R2: the ASTER-DEM used has a 30 m spatial grid, but everybody knows, that the vertical accuracy may vary up to 5 m and more. This is a major drawback in coastal lowlands, where just small height differences may cause large discrepancies in flooded areas. Better use LIDAR data if available,

A2: Thank you very much for your suggestion. In flood inundation simulations, the use of different DEM products can produce differences in inundation results. The reason is that different open-access DEMs use different observation satellites and algorithms, producing various vertical differences. This is another research direction of interest for our team, which has successfully simulated inundation differences due to differences in DEM products (Xu et al., 2021). This study compared the inundation results produced by six different open-source DEM products (SRTM, ASTER-DEM, AW3D, MERIT, NASADEM and CoastalDEM) under different flood return periods. Based on the results of this study, we finally selected the ASTER-DEM product that performs more stably under different flood scenarios. **Here, we choose the open-access DEM product due to funding and modeling power constraints.** We have added additional descriptions in the corresponding section of the manuscript. The Referee can read the new part in the following:

Line 109-111: *ASTER-DEM has been shown to be the most stable data performer among six types of open access DEM products (SRTM, ASTER-DEM, AW3D, MERIT,* *NASADEM and CoastalDEM) for flood inundation simulations with different return periods (Xu et al., 2021).*

[1] Xu, K., Fang, J., Fang, Y., Sun, Q., Wu, C. and Liu, M.: The importance of digital elevation models selection in flood simulation and a proposed method to reduce DEM errors: a case study in Shanghai, Int. J. Disaster Risk Sci., doi:10,1007/s13753-021-00377-z, 2021.

R3: the single forward modelling of the urban development may not concider the polycentric development of the agglomeration,

A3: Thanks for your comments. For most developing cities, especially fast-growing cities, the development of cities or urban agglomerations will show expansion patterns such as infill, edge-expansion, and outlying (Fig. 1). Numerous empirical studies by scholars have found that diverse patterns across cities are due to geographic and economic conditions. For example, Nanjing's urban expansion is mainly based on infill and outlying development (Xu et al., 2007). Beijing's urban expansion is based on concentric circles of urban outward expansion (Xie et al., 2007). While Hangzhou and Wuhan show a typical polycentric expansion pattern (Yue et al., 2010; Liu et al., 2011). In contrast, Shanghai's urban growth pattern is mainly based on infill and edge-expansion (Li et al., 2014; Zhou et al., 2020). Moreover, Shanghai's urban development is in transition to high-quality development, and it is difficult to appear a polycentric development pattern of outlying or satellite cities in the future.

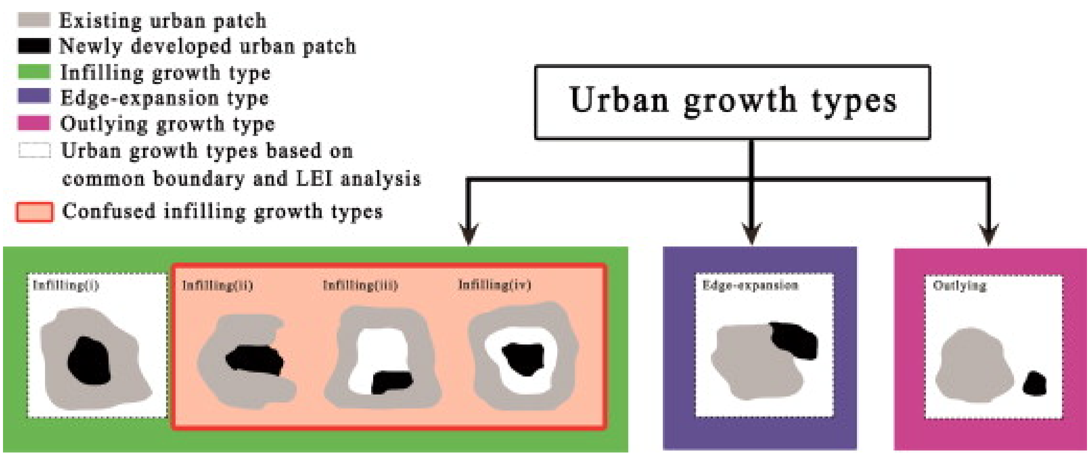

Fig. 1. Spatial modes for three urban growth types (From Shi et al, 2012).

In addition, the important influencing factors such as GDP, population and traffic roads are considered in our selected drivers of urban expansion, especially the application of FLUS model based on adaptive inertial competition mechanism has good self-organizing ability for urban expansion. Therefore, the combination of multiple expansion modes of future cities is also considered in our study.

[1] Shi, Y., Sun, X., Zhu, X., Li, Y., Mei, L.: Characterizing growth types and analyzing growth density distribution in response to urban growth patterns in peri-urban areas of Lianyungang City, Landscape & Urban Planning, 98(4), 425-433, 2010.

[2] Xu, C., Liu, M., Zhang, C., An, S., Yu, W., Chen, J.: The spatiotemporal dynamics of rapid urban growth in the Nanjing metropolitan region of China, Landsc. Ecol., 22, 925–937, 2007.

[3] Xie, Y., Fang, C., Lin, G., Gong, H., Qiao, B.: Tempo-spatial patterns of land use changes and urban development in globalizing China: A study of Beijing, Sensors, 7, 2881–2906, 2007.

[4] Yue, W., Liu, Y., Fan, P.: Polycentric urban development: The case of Hangzhou, Environ. Plan. A, 42, 563–577, 2010.

[5] Liu, Y., Yue, W., Fan, P.: Spatial determinants of urban land conversion in large Chinese cities: A case of Hangzhou, Environ. Plan. B, 38, 706–725, 2011.

[6] Li, H., Wei, Y., Huang, Z.: Urban Land Expansion and Spatial Dynamics in Globalizing Shanghai, Sustainability, 6, 8856-8875, 2014.

[7] Zhou, L., Dang, X., Sun, Q. and Wang, S.: Multi-scenario simulation of urban land change in Shanghai by random forest and CA-Markov model, Sustain. Cities Soc., 55, 102045, 2020.

R4: land subsidence is not equally everywhere. It depends very much on the ground substrate. Fluvial sediments may subside more than rocky underground. And it also depends on the anthropogenic use. Roads on sedimentary ground, where heavy trucks are driving each day may subside much more than anywhere else... It's not enough to analyze that statistically, one would hove to look attentive where this would happen. Interferometric evaluation of multitemporal microwave data would provide a propoer estimation on that...,

A4: Thanks for your comments. As you have analyzed, land subsidence in Shanghai is mainly caused by tectonic subsidence and compaction of sediments due to natural conditions and human activities. "(1) Compaction subsidence has a long history in Shanghai. It is one of the first few cities in China to suffer from serious land subsidence, with an average rate of 22.94 mm/year from 1921 to 2007 (Gong and Yang 2008). According to the monitoring data, compaction subsidence of Shanghai can be divided into three stages as: (i) rapid subsidence stage from 1921 to 1965 caused by excessive groundwater extraction; (ii) recovery stage from 1965 to 1985 with artificial recharge; (iii) slow subsidence stage from 1985 to 2007 due to large-scale construction of high-rise buildings and underground projects. Shanghai Geological Environmental Bulletin and land subsidence control plan estimate that **the average rate of compaction subsidence will be stabilized at 5 mm/year after 2010** (Shanghai Municipal Bureau of Planning and Land Resources 2007). (2) The crust of Shanghai has experienced gradual subsidence since the Pliocene. Based on the analysis of long-term monitoring data of very long baseline interferometer (VLBI) in the Sheshan bedrock, **the average rate of tectonic subsidence is estimated to have been nearly 1 mm/year** in Shanghai (Qian 1996). Since tectonic movement is relatively stable, it is assumed the rate of tectonic subsidence in Shanghai remain constant." --Reference to the analytical study by Yin et al. (Yin et al., 2013).

Therefore, prediction for land subsidence in Shanghai was generated by combining compaction subsidence and tectonic subsidence, resulting in a total land subsidence by 2030 and 2050 120 mm and 240 mm, respectively. However, due to the uncertainty of future anthropogenic activities and spatial distribution, there could be large variations in the projection.

We have rewritten the expressions related to the land subsidence projections for 2030 and 2050 in the corresponding places in the manuscript, in order to better understand the basis of our projections. The Referee can read the new part in the following:

Line 192-197: *Land subsidence in Shanghai is mainly caused by tectonic subsidence and compaction of sediments due to geological structure conditions and human activities. With reference to the long-term tectonic subsidence monitoring data of the very long baseline interferometer (VLBI) in the Sheshan bedrock and the land subsidence analysis rules of Yin et al (Yin et al., 2013). therefore, the total land subsidence is predicted to be 0.12 m and 0.24 m by 2030 and 2050, respectively. However, due to the uncertainty of future anthropogenic activities and spatial distribution, there could be large variations in the projection.*

[1] Qian Z.: Dftermination of the crustal vertical motion at Sheshan area, shanghai by VLBI, Annals of Shanghai Observatory Academia Sinica, 1996.

[2] Gong S., Yang S.: Effect of Land Subsidence on Urban Flood Prevention Engineering in Shanghai, Sci. Geogr. Sin, 28, 543–547, 2008.

[3] Shanghai Municipal Bureau of Planning and Land Resources (2007), Shanghai geological environmental bulletin, 2007.

[4] Yin, J., Yu, D., Yin, Z., Wang, J. and Xu, S.: Modelling the combined impacts of sea-level rise and land subsidence on storm tides induced flooding of the Huangpu River in Shanghai, China, Clim. Change, 119(3–4), 919–932, doi:10.1007/s10584-013-0749-9, 2013.

R5: the result showed a stronger inundation by the GE scenario than with the GP scenario. Flooding per se is not bad, so one would not rank the GE scenarion worse than the GP scenario, since it might consider clean air allies or urban green spaces. The authors mention that in their chapter 5.2 "Recommendations", but should emphasize that much more...

A5: Thank you very much for your suggestion. We strongly agree with the point that flooding is not inherently good or bad, but only makes a difference when it has an impact on human life. We have added a discussion in section 5.2 of the manuscript. The Referee can read the new part in the following:

Line 327-336: *Furthermore, our results show that the area of future urban flood risk varies by scenario. Although the GE scenario performs higher than the GP scenario in terms of flood inundation area, this does not mean that the GE scenario is worse. From the cases of advanced flood risk management countries such as the Netherlands (Kabat et al., 2009; Song et al., 2018), an important success lesson for future flood protection design is to leave enough space along coasts for wetland migration and leave space for nature. In other words, "soft strategies" such as "working with rivers and nature" are considered in the flood protection measures. Therefore, from this perspective the GE scenario may be a more likely future development scenario among these three scenarios. Future, it is necessary to learn from the practical experience of advanced countries to strengthen the development and construction of coastal wetlands and tidal flat ecosystems, and further reduce the residual risk through the adaptive regulation of coastal ecosystems and other soft strategies.*

[1] Kabat, P., Fresco, L. O., Stive, M. J. F., Veerman, C. P., van Alphen, J. S. L. J., Parmet, B. W. A. H., Hazeleger, W. and Katsman, C. A.: Dutch coasts in transition, Nat. Geosci., 2(7), 450–452, doi:10.1038/ngeo572, 2009.

[2] Song, J., Fu, X., Wang, R., Peng, Z.-R. and Gu, Z.: Does planned retreat matter? Investigating land use change under the impacts of flooding induced by sea level rise, Mitig. Adapt. Strateg. Glob. Chang., 23(5), 703–733, doi:10.1007/s11027-017-9756-x, 2018.

Specific comments

RC: Line27, 29: Change the location of the references in chronological order.

AC: We have changed the position of the references.

RC: Line29: Delete “the”.

AC: Done.

RC: Line31: Add “the…”

AC: Done.

RC: Line31: Add “the…”

AC: Done.

RC: Line38,44, 45, 48, 57: Change the location of the references in chronological order.

AC: Done.

RC: Line49: Add “need”

AC: Done.

RC: Line59-60: Change “how can combining different urban growth scenarios with climate change scenario analysis help inform preparedness for flood risks from climate change in urban flood risk assessments” with “how different urban growth scenarios combined with climate change scenario analysis may help to inform preparedness for flood risks from climate change in urban flood risk assessments”.

AC: Done.

RC: Line61: Add “areas may”

AC: Done.

RC: Line66: Add “to”

AC: Done.

RC: Line70: Change “west” with “West”. Add “(Fig. 1)”

AC: Done.

RC: Line71: Add “a”

AC: Done.

RC: Line73: Add “area”

AC: Done.

RC: Line78: Change “due to land subsidence and the increasing frequency and intensity of storm surge make Shanghai will become one of the most sensitive regions to the global climate change.” with “due to land subsidence and the increasing frequency and intensity of storm surges, Shanghai will become one of the most sensitive regions due to the global climate change.”.

AC: Done.

RC: Line89: Change “was” with “were”. Change “manually” with “visually”.

AC: Done.

RC: Line96: Add “area”

AC: Done.

RC: Line106: Change “validation” with “validated”.

AC: Done.

RC: Line110: Change the format

AC: Done.

RC: Line114: Change “complexity” with “complex”.

AC: Done.

RC: Line116: Change “combine” with “combining”.

AC: Done.

RC: Line133: Change “change” with “changes”.

AC: Done.

RC: Line135: Change “The FLUS model is an upgraded version of cellular automata model (Liu et al., 2017), which can solve…” with “The FLUS model is an upgraded version of a cellular automata model (CA-model, Liu et al., 2017) which can solve…”

AC: We have changed “The FLUS model is an upgraded version of a cellular automata model (Liu et al., 2017) which can solve…”, because the abbreviation of CA model has appeared in Line54

RC: Line139: Add “area, an”

AC: Done.

RC: Line142: Change “The difference is as follows:” with “The differences are as follows:”.

AC: Done.

RC: Line149: Add “the”

AC: Done.

RC: Line150: Change “which” with “where the”.

AC: Done.

RC: Line154: Add “the”

AC: Done.

RC: Line156-157: Change “combines” with “combining”. Change “is” with “are”. Add “an”

AC: Done.

RC: Line160-161: Add “considering”.

AC: Done.

RC: Line160-161: Change “To better validate the model before predicting future change, we compared output to the actual land use 2015.” with “To better validate the model before predicting for future change, we compared the output with the actual land use 2015.”

AC: Done.

RC: Line177: Change “scenario” with “scenarios”.

AC: Done.

RC: Line178-181: Change “which” with “with”. Add “a”. Change “followed to” with “following”.

AC: Done.

RC: Line186: Change “that is considered” with “to be”.

AC: Done.

RC: Line192-193: Change “Overall, the model accuracy outputs are measured shows an acceptable or good level of prediction, therefore the model is suitable for predicting changes in land use the Shanghai.” with “Overall, the measured model accuracy outputs showed an acceptable or good level of prediction, therefore the model is suitable for predicting changes in land use of the Shanghai area.”

AC: Done.

RC: Line205-208: Change “project, compare” with “projected, compared”.

AC: Done.

RC: Line211: Change “due to” with “since”.

AC: Done.

RC: Line216: in the text GP always comes before GE…, would avoid confusion…

AC: Thanks to the reviewer's suggestion, we have switched the positions of GE and GP in the figure.

RC: Line218: Change “Simulation results of different scenarios in 2030 and 2050.” with “Simulation results of different scenarios in 2030 (top) and 2050 (bottom).”.

AC: Done.

RC: Line227: Change “the submerged area increasing trends with time” with “the submerged area is increasing with time”.

AC: Done.

RC: Line234: Change the format

AC: Done.

RC: Line237: Add “area”

AC: Done.

RC: Line246: Change “new growth urban area” with “new grown urban areas”.

AC: Done.

RC: Line247: Add “scenarios”

AC: Done.

RC: Line249: Change “with the rapid expansion of the urban” with “with a rapid expansion of the urban area”.

AC: Done.

RC: Line253: Change “be reached” with “reach”.

AC: Done.

RC: Line255: Change “due to the average altitude of Shanghai is around 4 m” with “since the average altitude of Shanghai is only around 4 m”.

AC: Done.

RC: Line256-258: Change “Inundate of each land use type under different scenarios. The inundated areas of different land use types, including cropland, woodland, grassland and urban land, were calculated for each scenario, where a indicates new growth area of urban affected by flooding.” with “Inundation of each land use type under different scenarios. The inundated areas of different land use types, including cropland, woodland, grassland and urban land, were calculated for each scenario, where a indicates new grown areas of the urban class affected by flooding.”.

AC: Done.

RC: Line266: Add “it”

AC: Done.

RC: Line279: Change “future flood risks in coastal areas also are not fully reflected through using of hydrodynamic models,” with “future flood risks in coastal areas are also not fully reflected through the use of hydrodynamic models,”.

AC: Done.

RC: Line283: Change “not be” with “is not yet”.

AC: Done.

RC: Line285: Add “of”

AC: Done.

RC: Line291: Add “act”

AC: Done.

RC: Line300: Add “which”

AC: Done.

RC: Line303: Change “SLR” with “sea level rise”.

AC: Done.

RC: Line320: Add “the”

AC: Done.

RC: Line326: Change “potentially” with “potential”.

AC: Done.

RC: Line329: Add “areas”

AC: Done.

RC: Line330: Add “global warming”

AC: Done.

RC: Line331: Delete “have”

AC: Done.